Transportation and Habitation Objectives

Transportation and Habitation Goal: Develop and demonstrate an integrated system of systems to conduct a campaign of human missions to the Moon and Mars, living and working on the lunar and Martian surface, and a safe return to Earth.

TH-1:	Develop cislunar systems that crew can routinely operate to lunar orbit and lunar surface for extended durations.
TH-2:	Develop systems that can routinely deliver large surface elements to the lunar surface.
TH-3:	Develop systems to allow crew to live and operate safely on the lunar surface and lunar orbit for extended periods of time with scalability to continuous presence to visit areas of interest for scientific research, conduct Mars analog activities, support industrial utilization, and conduct utilization activities.
TH-4:	Develop a habitation system for crew in deep space for extended durations, enabling future missions to Mars.
TH-5:	Develop a transportation system that crew can routinely operate from the Earth-moon vicinity to Mars orbit and Martian surface.
TH-6:	Develop a transportation system that can deliver large surface elements from Earth to the Martian surface.
TH-7:	Develop systems for crew to live, operate, and explore on the Martian surface to address key questions with respect to science and resources.
TH-8:	Develop a system that monitors crew health and performance and provides medical care to the crew during long communication delays to Earth and in an environment that does not allow emergency evacuation nor terrestrial medical assistance.
TH-9:	Develop integrated human and robotic systems with inter-relationships that enable maximum science return from the lunar surface and from lunar orbit.
TH-10:	Develop integrated human and robotic systems with inter-relationships that enable maximum science return from the Mars surface and from Mars orbit.
TH-11:	Develop systems capable of returning large cargo mass from the lunar surface to the Earth, including the capabilities necessary to meet scientific sample return objectives.
TH-12:	Develop systems capable of returning large cargo mass from the Martian surface to the Earth, including the capabilities necessary to meet scientific sample return objectives.

Lunar and Martian Infrastructure Objectives

Lunar Infrastructure (LI) Goal: Create Global Lunar Utilization infrastructure where U.S. industry and international partners can maintain continuous robotic and human presence on the lunar surface for a robust lunar economy without NASA as the sole user, while accomplishing Mars testing and science objectives.

LI-1: Develop an incremental lunar power grid that is evolvable to support continuous human/robotic operation and is capable of scaling to global power utilization and industrial power levels.

LI-2: Develop Lunar surface, orbital, & Lunar to Earth communications, position, navigation and timing architecture capable of scaling to support long term science, exploration, and industrial needs.

LI-3: Demonstrate autonomous construction, precision landing, surface transportation, industrial scale ISRU and Advanced Manufacturing capabilities in support of future continuous human lunar presence and a robust lunar economy.

LI-4: Demonstrate technologies supporting cislunar orbital/surface depots, construction and manufacturing maximizing the use of in-situ materials, and support systems needed for continuous human/robotic presence.

Martian Infrastructure (MI) Goal: Create essential infrastructure to support initial human Mars demonstration.

MI-1: Develop Mars Surface Power sufficient for the initial human Mars demonstration mission.

MI-2: Develop Mars surface, orbital, & Mars to Earth communications to support the initial human Mars demonstration mission.

MI-3: Develop and demonstrate entry, descent, and landing (EDL) systems capable of delivering crew and large cargo to the Martian surface.

Operations Objectives

Operations Goal: Conduct human missions on the surface and around the Moon followed by missions to Mars. Using a gradual build-up approach, these missions will demonstrate technologies and operations to live and work on a planetary surface other than Earth, with a safe return to Earth at the completion of the missions.

OP-1: Conduct human research and technology demonstrations on the surface of the Earth, low Earth orbit platforms, cislunar platforms, and on the surface of the moon, to evaluate the effects of extended mission durations on system performance, reduce risk, and shorten the timeframe for system testing and readiness prior to the first human mission to Mars.

OP-2: Optimize operations, training and interaction between crew, the support team on Earth, orbital support and a Martian surface team considering communication delays, autonomy level, and time required for an early return to the Earth.

OP-3: Characterize accessible lunar resources, gather scientific research data, and analyze potential reserves to satisfy science and technology objectives and enable ISRU on successive missions.

OP-4: Establish command, control and coordination and processes that will support expanding human missions at the Moon and Mars.

OP-5: Operate surface mobility systems using extra-vehicular activity (EVA), suits, tools and vehicles.

OP-6: Evaluate, understand, and mitigate the impacts on crew health and performance of a long deep space orbital mission, followed by partial gravity surface operations on the Moon.

OP-7: Validate readiness of systems and operations to support crew health and performance on the first human mission to Mars.

OP-8: Demonstrate the capability to find, service, upgrade, or utilize instruments and equipment from robotic landers or previous human missions on the surface of the Moon and Mars.

OP-9: Demonstrate the capability of integrated robotic systems to support and augment the work of crewmembers on the lunar surface, and in orbit around the Moon.

OP-10: Demonstrate the capability to remotely operate robotic systems that are used to support crew members on the Lunar or Martian surface, from the Earth or from orbiting platforms.

OP-11: Demonstrate the capability to use commodities produced from planetary surface or in-space resources to reduce the mass required to be transported from Earth.

Science Objectives (1 of 2)

Exploration Science (ES) Goal: Conduct science on the Moon and in cislunar space, using integrated human and robotic methods and advanced techniques, to address high priority U.S. scientific questions about the Moon and to demonstrate methods for future science by astronauts beyond the Earth-Moon system.

ES-1: Conduct human field geology on the surface and select high priority sample specimens for return to Earth.

ES-2: Demonstrate advanced techniques and tools to enable Earth-based scientists to remotely guide astronaut surface activities.

ES-3: Enable in-situ research by delivering science instruments to the lunar surface at various locations and returning high priority samples to Earth.

ES-4: Survey sites, conduct in-situ measurements, and identify/stockpile samples for later astronaut evaluation or retrieval.

ES-5: Demonstrate retrieval of frozen volatile deep core samples from permanently shadowed regions on the Moon.

ES-6: Establish methods and systems to allow a large number of science instruments to conduct planetwide long-term measurements.

ES-7: Establish a scientific laboratory at the lunar South Pole to conduct high value lunar surface science.

ES-8: Utilize Mars Sample Return (MSR) mission results to optimize human-led science sampling campaigns on Mars, sample return to Earth and characterize landing sites.

Lunar/Planetary Science (LPS) Goal: Address those high priority planetary science questions which are best accomplished by on-site human explorers on the Moon and Mars, aided by robotic systems.

LPS-1: Conduct studies of planetary processes (e.g., impact, volcanism, tectonism, regolith formation, and atmosphere dynamics) to understand the dynamics and chronology of planet evolution.

LPS-2: Collect fundamental data to understand the origin, distribution, abundance, composition, transport, and sequestration of volatiles throughout the solar system.

LPS-3: Conduct analyses to constrain the chronology and dynamics of early Solar System history, including planetary differentiation, early bombardment history, and the formation of the Earth-Moon system.

LPS-4: Collect samples over a long traverse/duration in the South Pole Aitken Basin and deliver the samples to astronauts for return to Earth.

Science Objectives (2 of 2)

Heliophysics Science (HS) Goal: Address those high priority heliophysics science and space weather questions which are best accomplished using a combination of human explorers and robotic systems on the Moon and in cislunar space.

HS-1: Understand space weather phenomena to enable improved prediction of the dynamic space environment for deep space exploration.

HS-2: Remotely observe the Sun and Geospace and conduct in-situ measurements in the deep magnetotail and pristine solar wind, to understand the dynamics of the connected Sun-Earth system.

HS-3: Discover and characterize fundamental plasma processes including dust-plasma interactions, using the cis-lunar environment as a laboratory.

Biological and Physical Science (BPS) Goal: Understand fundamental biological effects when organisms are present in fractional-gravity and deep-space environments, to gain new scientific understanding and information to guide system development.

BPS-1: Understand the fundamental biological effects of short and long duration exposure to the lunar environment on human physiology and disease.

BPS-2: Understand the fundamental biological effects of short and long duration exposure to the lunar environment on plants used to provide crew nutrition/behavioral health.

BPS-3: Understand the fundamental biological effects of short and long duration exposure to the lunar environment on the survival and adaptation of microbes associated with the crew, plants, and the built environment.

BPS-4: Understand transient or permanent physiological changes on several generations of organisms.

Astrophysics Science (AS) Goal*:* Preserve the far side of the Moon as a “radio-free zone” for future radio astronomy experiments.

AS-1: Monitor the radiofrequency environment on the lunar far side to enable future far side radioastronomy activities.

Glossary of Terms

Architecture: A set of functional capabilities, their translation into elements, their interrelations and operations. The architecture enables the implementation of various mission scenarios that achieve a set of given goals and objectives.

Campaign: A series of interrelated missions that together achieve agency goals and objectives.

Continuous presence: Steady cadence of human/robotic missions in subject orbit/surface with the desired endpoint of 365/24/7 operations.

Demonstrate: NASA deploys an initial capability to enable system maturation and future industry growth in alignment with architecture objectives.

Develop: NASA designs, builds, and deploys a system, ready to be operated by the user, to fully meet architectural objectives.

Explore: Excursion-based surface expeditions focused on science and technology tasks.

Global: Infrastructure and capabilities that support human and robotic operations and utilization across the subject planetary surface.

Incremental: Building compounding operational capabilities within the constraints of schedule, cost, risk, and access.

Glossary of Terms

Live: The ability to conduct activities beyond tasks on a schedule. Engage in hobbies, maintain contact with friends and family, and maintain healthy work-life balance.

Mission: A major activity required to accomplish an Agency goal or to effectively pursue a scientific, technological, or engineering opportunity directly related to an Agency goal. Mission needs are independent of any particular system or technological solution.

Mobility: Powered surface travel that extends the exploration range beyond what is possible for astronauts to cover on foot. Spans robotic and crewed systems, and can be accomplished on and above the surface.

Routine: Recurring subject operations performed as part of a regular procedure rather than for a unique reason.

Scalability: Initial systems designed such that minimal recurring DDT&E is needed to increase the scale of a design to meet end state requirements.

Utilization: Use of the platform, campaign and/or mission to conduct science, research, test and evaluation, public outreach, education, and industrialization of the subject body.

Validate: Confirming that a system satisfies its intended use in the intended environment (Did we build the right system?).

Glossary of Terms

INHERENT ACROSS ALL OBJECTIVES

International Partnerships: partner with international community to promote resilience and achieve common goals and objectives.

Industry Collaboration: collaborate with commercial partners to create most effective solutions and achieve common goals and objectives.

Return Crew Safely: return crews to Earth in a safe manner at the conclusion of missions, or in the event crew health requires an earlier-than-planned return, while minimizing impacts to life expectancy.

Maximize Crew Time: maximize crew time for science and engineering activities across all systems and operations.